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Forecasting enlisted attrition in the United States Marine Corps by grade and years of service

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THESIS

FORECASTING ENLISTED ATTRITION IN THE UNITED STATES MARINE CORPS BY GRADE AND YEARS OF SERVICE

by

Bill C. Tamayo Jr.

March 2011

Thesis Advisor:	Chad Seagren
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FORECASTING ENLISTED ATTRITION IN THE UNITED STATES MARINE CORPS BY GRADE AND YEARS OF SERVICE

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Submitted in partial fulfillment of the
requirements for the degree of

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The purpose of this thesis is to analyze historical United States Marine Corps enlisted attrition behavior and apply time series forecasting techniques by grade and Years of Service in order to identify methods to improve manpower analysts' ability to effectively forecast attrition behavior. This study compared the results of one to five-year Moving Average models and the results of one to five-year Weighted Moving Average models based on two Measures of Effectiveness, Mean Square Error and the Mean Absolute Percent Error. The results of the Friedman test indicate statistical significance of the results in relation to the Mean Square Error of the one to two-year Moving Average models. This thesis demonstrates that in most cases, a simple one-year Moving Average more effectively estimates attrition behavior than the other Moving Average or Weighted Moving Average models analyzed.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFADBD	Armed Forces Active Duty Base Date
CNA	Center for Naval Analysis
CSV	Comma Separated Values
DoD	Department of Defense
EAS	End of Active Service
ECFC	Enlisted Career Force Controls
FTAP	First Term Alignment Plan
FY	Fiscal Year
M&RA	Manpower and Reserve Affairs
MA	Moving Average
MAPE	Mean Absolute Percent Error
MCRC	Marine Corps Recruiting Command
MCRD	Marine Corps Recruit Depot
MOE	Measure of Effectiveness
MOS	Military Occupational Specialty
MPMC	Military Personnel, Marine Corps
MPP	Manpower Plans and Budget Division
MPP-20	Enlisted Plans section of MPP
MPP-50	Manpower Plans Integration and Analysis section of MPP
MSE	Mean Square Error
NEAS	Non-End of Active Service
NPS	Naval Postgraduate School
O&M	Operations and Maintenance
OCS	Officer Candidates School
PMOS	Primary Military Occupational Specialty
SAS	Statistical Analysis Software
SSN	Social Security Number
TFDW	Total Force Data Warehouse
TOA	Total Obligation Authority
USMC	United States Marine Corps
WMA	Weighted Moving Average
YOS	Years of Service

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EXECUTIVE SUMMARY

Manpower and personnel management costs are significant in the Marine Corps. The mismanagement of any area in the field of manpower analysis can impact the operational readiness of the entire Marine Corps. The Marine Corps must now operate in a more fiscally constrained environment and continue to provide the same level of effectiveness on the battlefield. Over 90% of the Marine Corps' total force are enlisted Marines and as a result, the accurate management of these personnel is most critical. As a portion of the manpower planning process, the forecasted attrition of enlisted personnel is required to effectively execute related tasks by manpower analysts.

The purpose of this thesis is to analyze historical United States Marine Corps enlisted attrition behavior and apply time series forecasting techniques by grade and Years of Service in order to identify methods to improve manpower analysts' ability to effectively forecast attrition behavior. The scope of this study is limited to active duty enlisted Marines in the grades of E-1 through E-9, and Years of Service between one and thirty years. Observed attrition behavior is used as the basis of accuracy for the Moving Average and Weighted Moving Average models according to two Measures of Effectiveness, Mean Square Error and Mean Absolute Percent Error. The difference in model performance is measured for statistical significance utilizing the Friedman Test.

This thesis demonstrates that in most cases, a simple one-year Moving Average model more effectively estimates attrition behavior than other Moving Average or Weighted Moving Average models. Based on this analysis, the recommendation to MPP-20 and MPP-50 is that the use of a one-year Moving Average model is the most effective way to estimate enlisted attrition rates in the Marine Corps by grade and Years of Service, regardless of the Measure of Effectiveness of either the Mean Square Error or the Mean Absolute Percent Error.

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I began this journey twenty-one months ago, arriving in Monterey, California, with both my father and my wife, and expecting our first child. Along the way, my wife gave birth to our daughter Brianna, and a short six months later, my father passed away. Although very proud of what his son is accomplishing in life, his dream of having a grandson did not come to be during his time on this earth. A short time after my father's memorial service, my wife and I found out that we were expecting another child. In January of 2011, my father's dream was finally realized when Bill C. Tamayo III entered this world.

Now that my family is entering another chapter of our life and moving to the east coast, I cannot help but be thankful for having the opportunity to be a Marine officer, a father, and husband to my wonderful wife. Without those pillars of life, there is no way that I would be in the position that I am. So, to my father who gave me so much during his life, I owe everything that I was, that I am, and what I will be to you. You will always be with us, and not a day goes by without you in our thoughts. I know that you are looking down on us as a very proud father and grandfather. We love you and miss you tremendously!

My beautiful wife Tina is the reason that I have made it through the recent ups and downs of life. She has sacrificed so much to be a great mother to our children and a loving wife to me. Whenever I need an answer, she is always ready to give me advice. So to my loving wife, thank you for everything, and I look forward to spending the remainder of our life together.

Lastly, I must thank all of my professors at the Naval Postgraduate School for preparing me for my duty in the years ahead. Special thanks goes to Major Chad Seagren for taking me in and showing me just a bit of what it takes to be a professional in the field of Marine Corps manpower analysis.

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I. INTRODUCTION

A. BACKGROUND

Manpower and personnel management costs consume significant portions of the Military Personnel, Marine Corps (MPMC) budget. More importantly, however, the consequences of inaccuracy in these areas can have dramatic results on the operational readiness of the Marine Corps. The Fiscal Year (FY) 11 end strength in the Marine Corps is 202,100 Marines, and approximately 90 percent of that total force are enlisted Marines. The FY11 MPMC budget is $13.3 billion, which is approximately 50 percent of the Marines Corps' total baseline Total Obligation Authority (TOA) (Concepts & Programs 2010). Of the 13 separate budget accounts in the Marines Corps, the MPMC account is the primary account to receive full obligation whether or not it was budgeted correctly, which can result in partial obligation in any of the other 12 accounts. This was the case when the over budget of FY's 01–02 end strength resulted in the re-allocation of $200 million from the Operations and Maintenance (O&M) account (Hattiangadi, Kimble, Lambert, Quester 2005). This type of miscalculation is costly, not only in budgeted dollars, but the impact on operational readiness of the entire Marine Corps can suffer more significant consequences while engaged in combat operations overseas.

The Marine Corps must be able to operate in a more fiscally and personnel constrained environment than what the Corps is accustomed to, based on the past decade of combat operations overseas. In his testimony to the House Armed Services Committee on 1 March 2011, General Amos stated, "The Marine Corps is re-posturing and rebalancing for the future." He also introduces the term "middle-weight force" to describe the capability that is currently missing between the special operations forces and conventional units. The Marine Corps will fill that gap and, as a result, "The drawdown of our active component from 202,100 to 186,000 must be conditions based, and only after completion of our mission in Afghanistan" (Amos 2011).

The reduction of these approximately 16,000 active duty Marines is not a simple task and must be effectively managed by manpower analysts. In preparation of these

reductions, the enlisted manpower analysts working in the Manpower Plans, Programs, & Budget branch (MPP), within the Manpower and Reserve Affairs (M&RA) department, play a vital role in any manpower and personnel analysis. Due to the large proportion of enlisted Marines, Enlisted Plans (MPP-20) and Integration and Analysis (MPP-50) sections are the lead agencies dealing directly with the effects of reductions on the total force. Reducing end strength by any significant amount of Marines will have important consequences on the budget, but finding the appropriate time frame to reduce the force while minimizing the adverse impacts on retention, promotion and retirement within the Marine Corps is vital.

The application of time series forecasting techniques to analyze enlisted attrition behavior by grade and Years of Service (YOS) is an important part of the manpower management process. This thesis demonstrates that in most cases, a simple one-year Moving Average (MA) more effectively estimates attrition behavior than other MA or Weighted Moving Average (WMA) models.

B. PURPOSE

The purpose of this thesis is to analyze historical United States Marine Corps (USMC) enlisted attrition behavior and apply time series forecasting techniques by grade and YOS in order to identify methods to improve manpower analysts' ability to effectively forecast attrition behavior. The primary research questions that will focus this analysis are:

1. Of the techniques most accessible to manpower analysts, which best forecast enlisted attrition behavior in the Marine Corps by grade and YOS?

2. How does the choice of technique depend on the measure of effectiveness?

C. SCOPE AND METHODOLOGY

This study analyzes enlisted attrition behavior utilizing time series forecasting techniques based on grade and YOS combinations. The scope of this study is limited to active duty enlisted Marines categorized in the grades of E-1 through E-9, and YOS between one and thirty years. This study applies the service limits for grades E-4 through

E-9 found in the Enlisted Career Force Controls (ECFC) in order to standardize the estimates. Observed attrition rates serve as the baseline against which the model performance is measured. For the purpose of this study, the term attrition is defined as any enlisted Marine that leaves active duty, regardless of the reasoning. Below are the categories of attrition used in this study.

1. End of Active Service (EAS)

    a. First Term – Enlisted Marines who finish their initial obligated enlistment and do not re-enlist.
    b. Intermediate – Enlisted Marines who have re-enlisted at least once, but get out before a third re-enlistment (4–13 years).
    c. Careerists – Enlisted Marines who have re-enlisted at least three times (14–19 years).

2. Non-End of Active Service (NEAS)

    a. Recruit losses – Recruits who do not graduate from recruit training.
    b. Medical discharge – Enlisted Marines who are medically separated from the Marine Corps prior to their EAS.
    c. Administrative separation – Enlisted Marines who are administratively separated from the Marine Corps prior to their EAS.
    d. Punitive discharge – Enlisted Marines who are punitively discharged from the Marine Corps prior to their EAS.
    e. Deserter losses – Enlisted Marines who are on Unauthorized Absence status for 30 consecutive days.
    f. Death

3. Enlisted to Officer Transitions – Enlisted Marines who accept a commission in the Marine Corps.

4. Other Losses – Any other loss not categorized above.

D. ORGANIZATION OF THE STUDY

Chapter I introduces the thesis research topic and covers the background, purpose of the research and the scope and methodology behind this study. Chapter II provides a literature review of previous research that relates to this thesis topic that influence decisions and assumptions made during this study. Chapter III introduces the data and analysis software used to calculate enlisted attrition rates by grade and YOS. This chapter also describes in detail the methodology behind each step during the data analysis portion of this research. Chapter IV discusses the results found after the completion of the data analysis and applies the Friedman test to determine significance of those results. Chapter V summarizes the findings from Chapter IV and makes recommendations to MPP-20 and MPP-50 in regards to these findings.

II. LITERATURE REVIEW

A. INTRODUCTION OF PREVIOUS STUDIES

Before further discussion of this study, an overview of previous attrition literature that influenced this study is necessary. There are a number of attrition and loss studies about the Marine Corps. The term loss is synonymous with the term attrition, with the latter being used primarily in the remainder of this study. Throughout the research of these studies, many attempt to predict the future attrition behavior of Marines by using known variables of the individuals' demographic profile combined with their previous enlistment behavior. The ability to predict future behavior based on these known variables is possible in many cases when utilizing multivariate regression modeling techniques, but the accuracy of these predictions are influenced by unobservable variables that cannot be accounted for in these prediction models. In a military context, the choice of an individual to behave a certain way that directly affects their probability of attrition can be difficult to account for in these prediction models. As seen in Chapter I, there are a number of reasons for attrition in the Marine Corps and the ability to effectively forecast these losses on the total force are important in achieving operational readiness on the battlefield. The following studies are similar in their attempts to predict attrition behavior in the Marine Corps, but differentiate themselves in the approaches taken to achieve that objective. The aspects of each study that directly influence the decisions made in this thesis are thoroughly discussed in the following sections.

B. HATTIANGADI, KIMBLE, LAMBERT AND QUESTER (2005)

Prior to discussing previous studies on forecasting enlisted attrition in the Marine Corps, it is necessary to first understand the current manpower planning process used in the Marine Corps. A Center for Naval Analysis (CNA) report completed in 2005 provides a thorough analysis of the enlisted manpower planning process currently used in the Marine Corps. This report analyzes the existing loss forecasting methods used by manpower planners in Quantico, Virginia, assesses the effectiveness of those methods in

order to make improvements to those models, and documents this improved manpower management process for future reference by manpower planners. The CNA analysis also looks at the officer manpower plan model, but this thesis focuses on the enlisted manpower plan model portion of the CNA study. The purpose of including this report is to provide a basic understanding of the enlisted manpower planning process in the Marine Corps and to identify the methods currently employed by the manpower analysts to forecast enlisted attrition behavior.

The CNA study is a response for the need for an accurate manpower forecasting process in the Marine Corps. This is because of the large proportion of the Marine Corps budget that is spent on personnel “Manpower costs are about $9.4 billion annually, or almost 60 percent of the Marine Corps’ annual budget” (5) and the costly results of inaccurate forecasts.

> Estimates had been incorrect in the past due to the ad hoc nature of the loss forecasting processes. Previously there was no institutionalized and documented methodology for forecasting losses and no systematic attempt to improve existing loss-forecasting techniques. New planners relied on information they gleaned during overlap period with their predecessors and sometimes developed their own methods (1).

This documented history of inconsistent forecasting of attrition behavior in the Marine Corps provides the reasoning behind a review of the entire manpower planning process being used at the time of this study in 2005. The following paragraphs summarize the enlisted manpower plan model explained in the study.

The CNA report discusses some fundamental definitions and congressionally mandated requirements placed on the Marine Corps. The authors begin the analysis by explaining Title X end strength rules and the applicability to the Marine Corps manpower planning process. As defined in the study, end strength is the number of service members in a particular service on the last day of the FY, 30 September. Title X allows each service to exceed end strength by two to three percent. Current Marine Corps policy sets the maximum percentage of those who can be in the top six enlisted grades at 54 percent.

This congressionally mandated end strength target applies to the sum of active-duty Marine Corps officers and enlisted personnel. The fundamental end strength equation is:

Beginning strength – Losses + Gains = End strength

The end strength at the end of the previous FY is the beginning end strength of the next FY.

Before discussing the manpower planning process in the Marine Corps, an understanding of the basic components of the enlisted end strength model is required. The authors describe the six components and the sub-components of the enlisted manpower plan model. Chapter I of this study contains the definitions of four of the six components; this section will define the adjustments and gains models when appropriate. Figure 1 contains the six components of the complete manpower plan model. Each model is forecasted separately by month and grade.

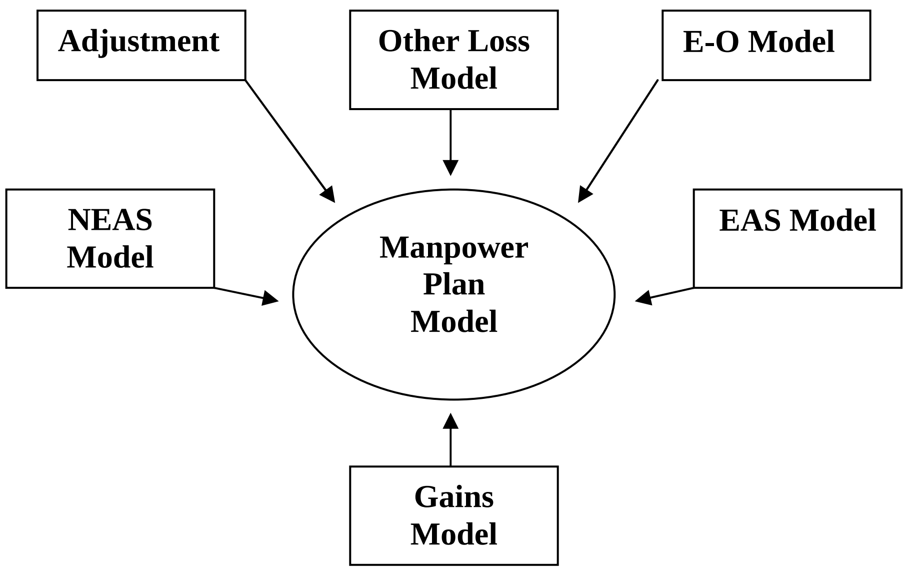

Figure 1. Marine Corps Enlisted End Strength Models

The EAS Loss Model is the most significant portion of the manpower plan model and requires special attention. This is because EAS losses account for over half of the active duty enlisted losses. These losses are broken down by first term, intermediate and careerists. First term EAS losses are managed by MPP-20 utilizing the First Term

Alignment Plan (FTAP). The FTAP is a steady state model that determines the number of reenlistments by Primary Military Occupational Specialty (PMOS). Each requirement is a “boatspace,” and recommended first term Marines cannot reenlist without an available boatspace in that PMOS. After calculation of the execution FY FTAP, or the number of first term Marines who will stay in the Corps in the execution FY, the enlisted strength planners apply a three-year average of previous monthly FTAP distributions to determine the percentage of Marines who will stay across the months in the execution FY. This percentage is multiplied by the FTAP for the execution FY by month and the resulting number is the forecasted number of first term Marines staying in the Corps. Intermediate and careerist EAS losses are calculated differently than first term EAS losses because all eligible Marines within these categories are allowed to reenlist. Intermediate and careerist losses are calculated by using the straight-line average of the previous three years of continuation rates at YOS 4–19. These rates are applied to the EAS population in the execution FY by month in order to calculate the number of Marines remaining in the Corps in these two zones. After calculation of all three sub-components of the EAS loss model, the monthly EAS losses are phased by grade. Utilizing a weighted average of the historical grade distribution of EAS losses, enlisted strength planners set the weighted average with up to four previous years’ data and set unequal weights within non-consecutive years if necessary. This weight differs by grade and is applied to total EAS losses by month in order to calculate the total amount of Marines remaining on active duty in the EAS loss model.

The next most important portion of the manpower plan model is the NEAS Loss Model. The NEAS losses account for 46 percent of all enlisted losses and include recruit, retirement, and category losses. Recruit losses occur at either of the two Marine Corps Recruit Depots (MCRD) and are calculated by gender. The first step prior to estimating recruit losses is to take into account recruit accession phasing which is established by Marine Corps Recruiting Command (MCRC) by trimester. To forecast recruit phasing rates in the execution FY, enlisted strength planners compute a four-year weighted average of historical monthly phasing rates by month and gender. Next, the estimated number of prior service contracts must be subtracted from both the male and female

accession numbers because these individuals are not required to go through recruit training. The planners must phase these male and female net accession numbers over the execution FY by multiplying the net accession number by the monthly accession phasing rate estimated for the FY. Lastly enlisted strength planners must forecast recruit loss rates by month and gender in order to phase losses over the execution year. Again, historical loss rates from the previous four years are used and averaged to estimate loss rates for the next FY. In order to forecast retirement losses, enlisted end strength planners take the average previous four years historical number of retirements in comparison to the actual number of retirement packages submitted during the previous FY. This requested and actual differential in retirement rates is used in the calculation of forecasted retirement losses and is distributed by month in concert with the average from the previous four years actual retirements by month. Category losses are defined as losses that occur after recruit training that are not counted as EAS or retirement losses. All of these category losses are forecasted together by month utilizing a weighted average of the previous three years' category losses or Monte Carlo simulations.

The Other Loss Model is utilized to account for enlisted Marines that are no longer on active duty, but have no loss code associated with that loss. The enlisted strength planners use a four-year weighted average of historical "other loss" data in order to forecast these losses.

The Enlisted to Officer Model accounts for the number of active duty enlisted Marines who receive a commission in the Marine Corps, which subsequently increases the number of officers, but decreases the number of enlisted Marines. Also, the civilians attending Officer Candidates School (OCS) are paid as E-5s in the Marine Corps while attending OCS. Consequently, the civilians that do complete OCS and receive a commission or do not complete OCS must be counted as enlisted losses.

The Gains Model encompasses all non-prior service accessions, prior service accessions, deserters and other gains. The majority of these gains are non-prior service accessions, which are not forecasted by the enlisted strength planners, but managed. All other gains components are forecasted the same by using a four-year weighted average and Monte Carlo simulations.

The Other Adjustments Model is the last phase of the enlisted manpower planning process and ensures that the end strength goal for the given FY is met after all the losses and gains have been forecast from the models described previously. The enlisted strength planners add in accessions to enlisted end strength and adjust it as necessary in order to achieve the mandated end strength number on the last day of the FY.

C. ORRICK (2008)

This Naval Postgraduate School (NPS) thesis from 2008 develops a regression modeling technique to forecast NEAS attrition. The study utilizes a logistic regression technique that identifies attributes of the individual Marines' demographic profile that are more likely to be associated with NEAS losses. The findings of the study predict NEAS losses for FY 2005–2007 with greater than 76 percent accuracy and misclassify EAS separations as NEAS losses at a rate below 25 percent. The purpose of including this thesis is to analyze a typical regression technique used in many attrition studies in order to identify the strengths and weaknesses of this type of analysis.

One weakness in the thesis is the significant reduction in the number of observations from data collection to final analysis. The data is from the TFDW and consists of three sets of data. The first data set encompasses all enlisted losses from 1 October 1997 to 30 April 2007. The second data set captures all enlisted accessions during that same period and the final data set is a snapshot of the enlisted end strength on 30 September 1997. All three data sets totaled 587,154 entries, but after cleaning and coding, the final data set consisted of 167,269 observations. This large difference is due to missing variables in a number of observations and is a common weakness in these types of regression techniques. Although not a fault on part of the researcher, this significant reduction in observations degrades the validity of the data in this thesis.

Another negative effect that the missing variables have on the thesis is in the application of the logistic regression model. The logistic regression model consists of the binary dependent variable of attrition and 51 independent variables that explain attrition behavior. The independent variables are personal and professional demographic information extracted from TFDW, and are the cause of the large reduction in

observations explained previously. Over 126,000 observations are missing separation codes, and were consequently deleted from the data set. The author notes that this amount of missing observations “may have an influence on the outcome of the models” (page 22). It is necessary in a logistic regression model to show the effects of the separation codes in explaining the relationship on attrition. The approximately 126,000 missing separation codes not only represent another weakness of the thesis, but also represent a weakness on model selection.

The application of a logistic regression model to forecast NEAS attrition is valid, but the large amount of discrepancies in the data degrades the validity of this thesis. Utilizing known independent variables in a proven logistic regression model to explain a binary dependent variable is a sound research methodology for this type of manpower research. The Receiving Operator Characteristics (ROC) curves analysis shows the logistic regression models performs well. This type of regression analysis is not feasible to use on a regular basis in the manpower planning process. This thesis shows that these types of regression models continue to provide insight into attrition behavior, although historical data inaccuracies are still the greatest challenge to the correct application of these models. The author recommends that further research in this area should be preformed utilizing survival analysis, by month and by MOS, which is the premise of the following thesis by Hall.

D. HALL (2009)

This NPS thesis from 2009 applies parametric modeling techniques to forecast enlisted attrition. The author includes those characteristics that influence attrition behavior in the model and combines them into one forecasting model. The thesis analyzes enlisted Marines entering the service until becoming a NEAS loss or exiting the service as an EAS loss. Hall uses personal and professional demographic characteristics, similar to the Orrick’s thesis, to determine if the characteristics can forecast future attrition behavior. The findings of the thesis are “that the use of survival analysis could be beneficial to not only forecast attrition, but also provide a descriptive assessment of attrition rates amongst occupation fields without loss of information due to averaging or

weighting probabilities" (v). The purpose of including this thesis is to analyze a survival analysis technique in order to identify the strengths and weaknesses of this type of analysis.

The strength of the thesis is a thorough data collection process and a methodological approach to its analysis. The master data set comprises of 25 individual data sets containing all enlisted Marines who entered in the Marine Corps between 1 January 1996 and 31 October 2008. The data sets capture all accessions per month and verify the continuation of service of those Marines who accessed in previous FY's. The master data set includes a "Personal Statistic" data set for each FY to accompany the accession data that provide updated information of each Marine's personal and professional characteristics as they changed over time. A final "Separation" data set is in the master data set to collect all separations per FY. Lastly, all observations in each of these three data sets are collapsed into one observation per Marine, capturing the entire length of service in the master data set. The initial master data set contained 419,893 individual observations, but 39,562 were dropped due to data inaccuracies with separation codes and gender. The final master data set consists of 376,710 observations, but 3,063 duplicate entries are not used in the analysis because of the unreliability of the data with Marines in a "Deserter Status." The master data set contains 88 personal and professional demographic variables, although not all 88 variables are used in estimations in the thesis.

An additional strength of the thesis is a thorough model selection process. The author estimates the data without covariates, progresses to a model with covariates and concludes with a test on the specific influences of the covariates have on the hazard rate. The hypothesis is "that transition rates (hazard rates) will decline at a monotonic rate as time increases" (37). The Gompertz model without covariates shows proof that enlisted transition rates decrease as enlistment time increases, supporting the hypothesis, but those results did not include the other explanatory variables that could influence transition rates. Including 56 parameters, the Gompertz model with covariates provides a better log likelihood value than the model without covariates. This fact supports the author's hypothesis and provides a better description of the hazard rate.

Similar to the previous thesis, a weakness of this study is that the findings are only as good as the data collected. Both studies show that the data from the TFDW is unreliable in the collecting of any number of explanatory variables, especially separation codes. Until the process of collecting and archiving data within the Marine Corps is improved, it is important to use explanatory variables that are more reliable. Examples of this are grade and YOS, which are easily extracted from TFDW and quickly calculated with analysis software. Both studies provide evidence that there are numerous explanatory variables than help explain attrition behavior, but there are still unobservable characteristics of each Marine not accounted for in the data, which contribute to attrition. Another weakness of this thesis is that survival analysis is not feasible to conduct by manpower planners in any regular interval. Simple, efficient and flexible modeling techniques are required in the manpower planning process.

The findings of this study provide further evidence of many of the same insights that manpower planners understand as common characteristics of attrition behavior. For example, the longer a Marine remains on active duty then the less likely that individual is to attrite, females have higher attrition rates than males, married Marines are less likely to attrite than single Marines and certain MOS's have higher attrition than others MOS's. Although both Gompertz models support the hypothesis and the model with covariates is more descriptive in its results, the findings of the thesis provide nothing significant to improve on the attrition forecasting methods currently being used by manpower planners.

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III. DATA

A. INTRODUCTION

This chapter focuses on the data collection, analysis software, and methodology behind the calculation of historic enlisted attrition rates by grade and YOS in the Marines Corps. This chapter also discusses the models used to forecast historic attrition rates by grade and YOS. The purpose of this chapter is to provide a thorough understanding of the data analysis process and assures validity of the findings in the following chapters of this thesis.

B. COLLECTION AND SUMMARY STATISTICS

This section summarizes the data collection process, the variables of each observation, and the final statistics. The data was extracted from the TFDW in 23 separate data sets. Each data set is a snapshot of enlisted end strength on 30 September of each FY beginning in 1987 and ending in 2009. Each observation contains five variables; the sequence number, Social Security Number (SSN), Armed Forces Active Duty Base Date (AFADBD), present grade code and PMOS code. The sequence number is used to identify each 30 September per FY. The SSN is used to locate each individual Marine and verification whether or not that particular Marine is still on active duty in the in the following FY. The AFADBD is used to calculate each Marine's YOS total at the end of each FY. YOS is calculated by actual years completed. For example, a Marine with 0 YOS has not yet completed one YOS and is any enlisted Marine with less than 12 months on active duty since their AFADBD. The present grade code is used to identify what each Marine's current grade is on 30 September of each FY. The PMOS code is not used in this study. The total number of observations of all 23 data sets is 3,778,491. Analyzing the results using SAS and applying the current service limits set forth in the ECFC, the final number of observations is 3,578,157. Table 1 displays the grade and YOS combinations used for this study.

Grade	YOS (Min)	YOS (Max)
E1	0	5
E2	0	5
E3	0	5
E4	1	8
E5	2	13
E6	5	20
E7	9	22
E8	14	27
E9	19	30

Table 1. Grade and YOS Combinations

C. ANALYSIS SOFTWARE

The primary means to manipulate the raw data extracted from TFDW, calculate historic enlisted attrition by grade and YOS combinations, and apply time series forecasting models to predict those historic rates was done using the SAS System for Windows V8. Microsoft Excel is also utilized to calculate the actual attrition rates by grade and YOS once the raw data was transformed into a usable format in SAS. The R software environment is used to calculate statistical significance of the results.

D. METHODOLOGY TO CALCULATE ATTRITION BY GRADE AND YEARS OF SERVICE

1. The first step in calculating enlisted attrition in the Marine Corps by grade and YOS is to import the 23 separate data sets extracted from TFDW into SAS v8 for Windows. The file extension used to save the data sets was in Comma Separated Values (CSV) format.

2. Before beginning any calculations, the characters representing a date in history were changed into recognizable date formats in SAS. Most importantly, the sequence numbers and AFADBD were changed to SAS date elements.

3. The next step is to calculate YOS for each observation by subtracting the sequence number date from the AFADBD for each data set. This

measurement of time is in days and is programmed in SAS to represent cumulative YOS by each additional twelve months of service on active duty.

4. Each data set is sorted by identification number and merged together. The below constraints are required to standardize the results.
    a. Drop observations if YOS is greater than 30.
    b. Drop observations if YOS is less than zero.
    c. Drop observations if AFADBD is blank.
5. The 23 data sets were merged consecutively by year. The beginning balance of enlisted personnel is the final end strength on 30 September 1987. Each following FY, observations are identified to continue on active duty or to have left active duty. Those observations that were not in the following FY's data are considered attrition. This annual continue and attrite information was collected by FY totals using SAS. This merged data is sorted by Present Grade and YOS.
6. This information is exported into two excel files that contain the total end strength data per FY in Appendix A and total attrition data per FY by each grade and YOS combination in Appendix B. The ECFC service limits are applied and the observations outside the constraints are dropped.
7. Lastly, the annual attrition rate is calculated for each grade and YOS combination in Appendix C. This is done by dividing the total attrition number for each FY by the total end strength of the previous FY.

E. FORECASTING MODELS

The initial forecasting technique used in this thesis is a simple MA model. This model utilizes the historic attrition rates calculated between FY87–08 in one- to five-year estimation models. As stated by Ragsdale (2001), "the predicted value of the time series in period $t + 1$ is simply the average of the k previous observations in the series" (491).

Ragsdale further elaborates that there is no general value of *k* that is best suited for a particular time series, thus multiple values of *k* should be compared in order to develop the best forecast. As the simplest form of forecasting, the MA is calculated in this thesis as a baseline model for comparison of the WMA models. Below is the equation for the calculation of the MA model. This equation and all other equations used in this chapter are from Ragsdale's textbook. For each grade *i*, and each YOS *j*, the calculation of the *k*-Year MA model is:

$$\hat{Y}_{i,\ j,t+1} = \frac{Y_{i,\ j,t} + Y_{i,\ j,t-1} + Y_{i,\ j,t-k+1}}{k}$$

where *i* and *j* are the grade and YOS combinations described in Table 1.

One disadvantage of the MA models is that the values of older data points can have disproportionate effects on the results. This is possible in the case of attrition in the military because during different periods in history result in significant increases or decreases in military manpower attrition from one year to the next because of congressionally mandated end strength requirements that fluctuate within the political and budgetary environment within the federal government.

The next forecasting technique used in this thesis is a WMA model. This model utilizes the historic attrition rates calculated between FY87–08 in one- to five-year model estimations. Due to the possible disproportionate effects on the results due to the older data points of the MA model, the WMA models allows for the manipulation of the relative importance of previous data points. Most WMA models weight the most recent data points more heavily and decrease the weights of the preceding time periods. Ragsdale notes, "Although the weighted moving average offers greater flexibility than the moving average, it is also a bit more complicated" (495). For each grade *i*, and each YOS *j*, the calculation of the following *k*-year WMA model is:

$$\hat{Y}_{i,\ j,t+1} = w_1 Y_{i,\ j,t} + w_2 Y_{i,\ j,t-1} + \ldots + w_k Y_{i,\ j,t-k+1}$$

$$\text{where,} \quad \sum_k w_k = 1$$

As before, i and j are the grade and YOS combinations described in Table 1. The increased complication of the WMA formula is that the values for k must be determined, but also the values of each weight must also be calculated. The relationship of each w is that the largest weight value (w_1) starts with the most recent data point (Y_t) and the subsequent weights ($w_2 \ldots w_k$) decrease in value in concert with the older data points (Y_{t-1}, $\ldots Y_{t-k+1}$). The summation of the weights in the formula must equal one. By utilizing *Solver* in the Microsoft excel software program, it is possible to determine those optimal values of the weights that minimize the error values.

The accuracy of the forecasts will be measured against the actual historic values previously calculated. This study uses the following Measures of Effectiveness (MOE).

$$MSE = \sum_{i,j} \frac{\left(Y_{i,j} - \hat{Y}_{i,j}\right)^2}{n}$$

$$MAPE = \frac{100}{n} \sum_{i,j} \left| \frac{(Y_{i,j} - \hat{Y}_{i,j})}{Y_{i,j}} \right|$$

Where, i and j are the grade and YOS combinations described in Table 1. For a particular model and a given FY, MSE is the squared error of each grade and YOS estimate averaged over all such estimates for that FY. Due to the unique distribution of enlisted Marines, with the overwhelming majority of the force in the E-1 through E-5 pay grades, and the E-6 through E-9 pay grades representing a small minority of the force, a pyramid force structure is observed. The densely populated bottom and sparsely populated top of the pyramid have different effects on the MSE and MAPE measurements of accuracy. As a result, MSE is the error measurement to utilize in the manpower planning process if it is more important to be accurate in the aggregate. MSE will tend to select the models that most accurately describe the most densely populated grade and YOS combinations, which are the E-1 through E-5 grade and YOS combinations calculated in this study.

On the other hand, observing the pyramid shape of the enlisted force structure, MAPE makes accuracy in predicting all grade and YOS combinations equally important. As a result, MAPE will tend to select models that explain all grade and YOS

combinations equally, which puts extra emphasis on getting those sparsely populated grade and YOS combinations at the top of the pyramid correct. The benefit of utilizing MAPE in measuring the accuracy of time series forecasts is that regardless of the difference in values, these differences are translated to a percent of total observations of the particular grade and YOS combination.

IV. RESULTS

A. GENERAL RESULTS FOR EACH MODEL

Applying the MA and WMA model to the historic enlisted attrition, the calculation of forecasted attrition numbers for FY88–08 was made for each grade and YOS combination in Table 1. This process was completed for five (one- to five-year models) forecasts, which resulted in 1,953 forecasts per each year category. The 1,953 forecasts represent 92 total grade and YOS combinations multiplied by 21 years of data. Then the MAPE and MSE were calculated for FY88–07 forecasts, which resulted in another (5 x 1,860) 9,300 error calculations. The reason for the 465 difference in the number of error results is because the historic attrition from FY09 is required in order to calculate the error for the FY08 forecast, but this thesis did not calculate the attrition from FY09. The performance of each of the models is compared for each year. Each of these data points are ranked on a scale from 1–5, based on the value of each FY to denote the lowest to highest error value. The following sections of this chapter discuss the specific results of each model and error calculation.

B. MOVING AVERAGE MODEL (MSE)

The FY average error values are in Table 2, and the plotted data points are in Figure 2. Table 2 reveals the average MSE results range from a low of 1,542 in the five-year MA model in FY05 to a high of 56,473 in the four-year MA model in FY07.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	5536	6661	10108	43500	7537	3423	3086	3160	2409	5925	4367	12772	3669	2854	2587	3268	2370	2168	6378	37679
2 YR		11138	15391	43936	21804	2952	3269	2711	4009	7691	8630	10200	13078	5931	4215	3591	1808	1660	4278	51942
3 YR			22714	39254	31855	7674	3559	3547	4438	9554	12214	8372	15463	14542	7087	4421	2210	1713	4687	52316
4 YR				35648	35163	11955	5285	3116	5570	11001	15133	7454	14589	19485	14072	5632	2652	1708	3851	56473
5 YR					35200	13613	8907	4527	5805	12965	17608	7957	13010	20597	20101	8573	3766	1542	3700	56016

Table 2. Average MSE Results by Fiscal Year

The plotted data points in Figure 2 reveal a similar trend in all the MSE results except for an increase in the one-year and two-year MSE values in FY99. The remaining three estimations during FY99 all decrease in average MSE. The spike in MSE in the early1990's period is due to the total number of attrition of enlisted Marines during that period is significantly different from the surrounding years due to the build up and execution of Operation Desert Storm/Shield and the corresponding release of troops in its aftermath. The number of attrition of enlisted Marines in FY88–91 averaged 30,000, but in FY92–93 the average increased to 34,000 and returned to the 30,000 average until FY03.

The spike in MSE in FY07 period is due to the decrease in enlisted attrition in FY05–08. The average dropped to around 26,500 during the this period because the Marine Corps was increasing end strength from around 160,000 in FY05 to nearly 178,000 enlisted Marines in FY08.

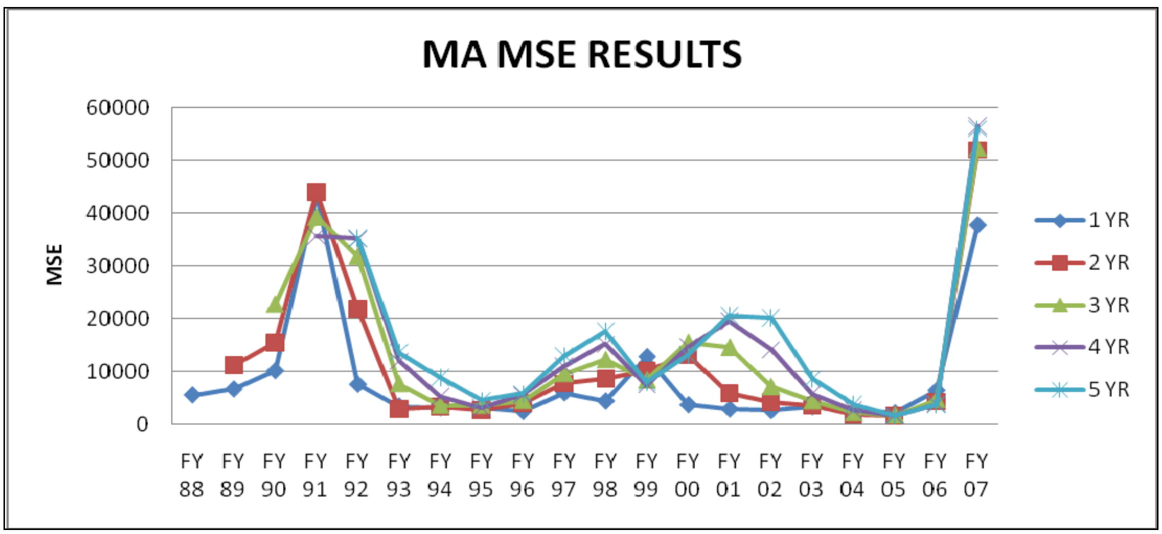

Figure 2. Moving Average MSE Results

The rankings in Table 3 (less FY88-91), reveal that the one-year MA MSE is lowest during thirteen years, the two-year MA MSE is lowest during three years, the three-year MA MSE is never the lowest, the four-year MA MSE is lowest during one year, and the five-year MA MSE is lowest during two years.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	1	1	1	3	1	2	1	3	1	1	1	5	1	1	1	1	3	5	5	1
2 YR		2	2	4	2	1	2	1	2	2	2	4	3	2	2	2	1	2	3	2
3 YR			3	2	3	3	3	4	3	3	3	3	5	3	3	3	2	4	4	3
4 YR				1	4	4	4	2	4	4	4	1	4	4	4	4	4	3	2	5
5 YR					5	5	5	5	5	5	5	2	2	5	5	5	5	1	1	4

Table 3. Moving Average MSE Rankings

The Friedman test is used to determine the statistical significance of the results. The hypotheses of the Friedman Test are:

H_0: Each ranking of the random variables within a block is equally likely (i.e., the treatments have identical effects).

H_1: At least one of the treatments tends to yield larger observed values than at least one other treatment.

The test of the null hypothesis that there is no difference in the effectiveness of any of these models suggests sufficient evidence exists to reject the null hypothesis (p-value .003). The post hoc multiple comparison of the five models is shown in Table 4.

Model		
1-Year	A	
2-Year	A	
3-Year	A	B
4-Year		B
5-Year		B
*Levels not connected by same letter are significantly different		

Table 4. Post Hoc Multiple Comparison of Moving Average (MSE) Models

The one-year and two-year models are significantly different and better in comparison to the four and five-year models. The three-year model is not significantly different from the four other year models.

C. MOVING AVERAGE MODEL (MAPE)

The average error values for each FY are in Table 5 and the plotted data points are in Figure 3. Table 5 reveals the average MAPE results range from a low of 0.149 in the three-year MA model in FY98 to a high of 0.327 in the five-year MA model in FY96.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	0.213	0.286	0.264	0.262	0.259	0.289	0.265	0.231	0.242	0.215	0.158	0.242	0.194	0.197	0.225	0.228	0.210	0.262	0.286	0.230
2 YR		0.261	0.262	0.269	0.262	0.266	0.295	0.277	0.253	0.179	0.157	0.212	0.206	0.209	0.242	0.207	0.208	0.230	0.227	0.201
3 YR			0.270	0.251	0.262	0.253	0.284	0.303	0.275	0.190	0.149	0.209	0.227	0.239	0.257	0.208	0.210	0.194	0.213	0.208
4 YR				0.251	0.275	0.235	0.251	0.311	0.320	0.226	0.172	0.196	0.238	0.238	0.293	0.222	0.208	0.194	0.226	0.205
5 YR					0.273	0.247	0.240	0.284	0.327	0.273	0.211	0.204	0.242	0.249	0.313	0.246	0.210	0.196	0.232	0.184

Table 5. Average MAPE Results by Fiscal Year

The plotted data points in Figure 3 reveal a similar trend in all the MAPE results except for an increase in the MAPE of the one-year and two-year estimates in FY99 then a decrease in FY00. The remaining three years' average MAPE results increase during both FY99 and FY00.

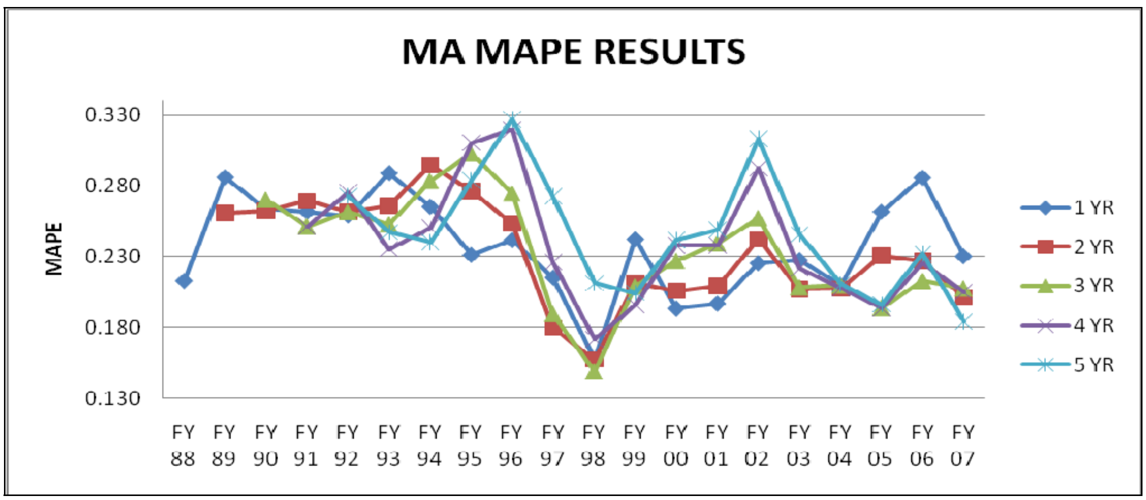

Figure 3. Moving Average MAPE Results

The MAPE rankings in Table 6 (less FY88–91), reveal that the one-year MA MAPE is lowest during six years, the two-year MA MAPE is lowest during three years, the three-year MA MAPE is the lowest during two years, the four-year MA MAPE is lowest during three years, and the five-year MA MAPE is lowest during two years.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	1	2	2	3	1	5	3	1	1	3	3	5	1	1	1	4	4	5	5	5
2 YR		1	1	4	3	4	5	2	2	1	2	4	2	2	2	1	1	4	3	4
3 YR			3	2	2	3	4	4	3	2	1	3	3	4	3	2	3	2	1	3
4 YR				1	5	1	2	5	4	4	4	1	4	3	4	3	2	1	2	2
5 YR					4	2	1	3	5	5	5	2	5	5	5	5	5	3	4	1

Table 6. Moving Average MAPE Rankings

A Friedman Test of the null hypothesis that there is no difference in the effectiveness of any of these models reveals insufficient evidence exists to reject this hypothesis (p-value 0.2).

D. WEIGHTED MOVING AVERAGE MODEL (MSE)

The *Solver* add-in for *Microsoft Excel* applies the equation introduced in Chapter III and selects the values for each weight (w_n) that minimizes the MSE or MAPE for that model, over the course of all years in the dataset. In this case, the optimal weights calculated using *Solver*, give the majority of the weight to the year closest to the current year. The optimal weights in Table 7 state that essentially all WMA MSE models are best estimated as essentially a one-year MA model.

	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5
2-Year	1	0			
3-Year	1	0	0		
4-Year	0.9542	0	0	0.0458	
5-Year	0.9971	0	0	0	0.0029

Table 7. Optimal MSE Weights Calculated Using Solver

The FY average error values are in Table 8 and the plotted data points are in Figure 4. Table 8 reveals the average MSE results range from a low of 2,036 in the four-year WMA model in FY05 to a high of 43,500 in the one-year through three-year WMA model in FY91.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	5536	6661	10108	43500	7537	3423	3086	3160	2409	5925	4367	12772	3669	2854	2587	3268	2370	2168	6378	37679
2 YR		6661	10108	43500	7537	3423	3086	3160	2409	5925	4367	12772	3669	2854	2587	3268	2370	2168	6378	37679
3 YR			10108	43500	7537	3423	3086	3160	2409	5925	4367	12772	3669	2854	2587	3268	2370	2168	6378	37679
4 YR				41297	8236	3006	2904	3009	2497	6202	4800	11710	3807	3485	3014	3152	2232	2036	6092	38920
5 YR					7560	3390	3087	3153	2415	5949	4397	12701	3662	2879	2616	3238	2363	2153	6364	37723

Table 8. Average MSE Results by Fiscal Year

The plotted data points in Figure 4 reveal a nearly identical trend in all the year MSE results. The majority of the years have the exact same average MSE results and the biggest difference in MSE values is 2,203 in FY91 in the four-year WMA model in comparison to the three other models' MSE results that year.

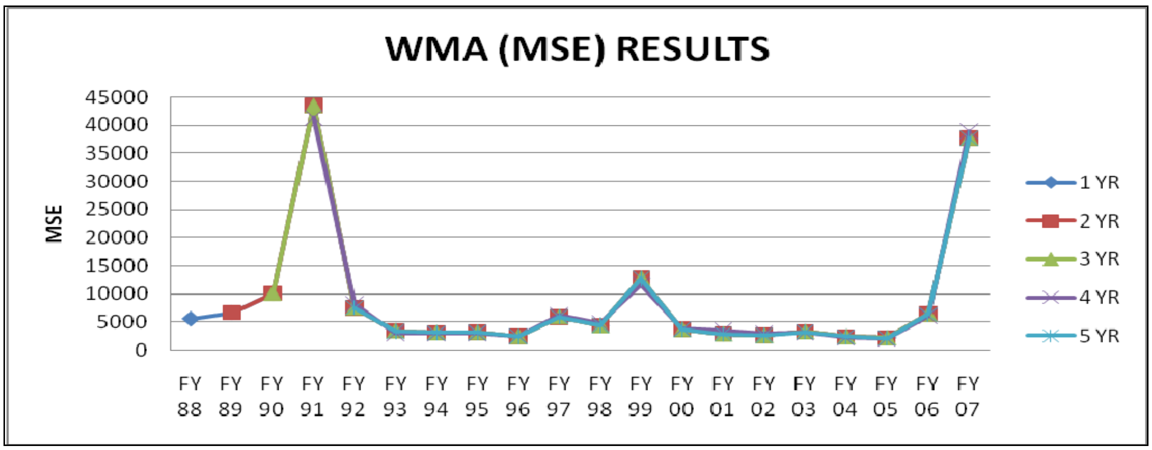

Figure 4. Weighted Moving Average MSE Results

The MSE rankings in Table 9 (less FY88-91), reveal that the one-year through three-year WMA MSE is lowest during seven years, the four-year WMA MSE is lowest during eight years, and the five-year WMA MSE is lowest during one year.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	1	1	1	2	1	3	2	3	1	1	1	3	2	1	1	3	3	3	3	1
2 YR		1	1	2	1	3	2	3	1	1	1	3	2	1	1	3	3	3	3	1
3 YR			1	2	1	3	2	3	1	1	1	3	2	1	1	3	3	3	3	1
4 YR				1	3	1	1	1	3	3	3	1	3	3	3	1	1	1	1	3
5 YR					2	2	3	2	2	2	2	2	1	2	2	2	2	2	2	2

Table 9. Weighted Moving Average MSE Rankings

A Friedman Test of the null hypothesis that there is no difference in the effectiveness of any of these models reveals insufficient evidence exists to reject this hypothesis (p-value 1.0).

E. WEIGHTED MOVING AVERAGE MODEL (MAPE)

The optimal weights in Table 10 calculated using *Solver*, give over 65% of the weight to the year closest to the current year except for in the two-year WMA model.

	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5
2-Year	0.3044	0.6956			
3-Year	0.6711	0.1985	0.1305		
4-Year	0.6628	0.1937	0.1187	0.0248	
5-Year	0.6637	0.2078	0.0965	0.0320	0

Table 10. Optimal Weights Calculated Using Solver

The FY average error values are in Table 11 and the plotted data points are in Figure 5. Table 11 reveals the average MAPE results range from a low of .149 in the three WMA model in FY98 to a high of .289 in the one-year WMA model in FY93.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	0.213	0.286	0.264	0.262	0.259	0.289	0.265	0.231	0.242	0.215	0.158	0.242	0.194	0.197	0.225	0.228	0.210	0.262	0.286	0.230
2 YR		0.268	0.252	0.260	0.253	0.252	0.277	0.252	0.244	0.189	0.153	0.221	0.196	0.198	0.230	0.211	0.205	0.239	0.247	0.196
3 YR			0.254	0.250	0.251	0.238	0.265	0.254	0.243	0.190	0.149	0.222	0.202	0.208	0.231	0.210	0.205	0.226	0.245	0.197
4 YR				0.250	0.252	0.235	0.260	0.255	0.247	0.192	0.150	0.221	0.202	0.206	0.234	0.209	0.204	0.225	0.245	0.196
5 YR					0.253	0.237	0.261	0.255	0.247	0.192	0.150	0.220	0.201	0.204	0.234	0.209	0.204	0.226	0.245	0.195

Table 11. Average MAPE Results by Fiscal Year

The plotted data points in Figure 5 reveal a similar trend in all the results of the MAPE except for an increase in the MAPE of the one-year model in FY93 when all other

MAPE results decrease during that year. The one-year MAPE results also decreases in FY95 and increase in FY96, when all other model MAPE results decrease in FY95 and in FY96.

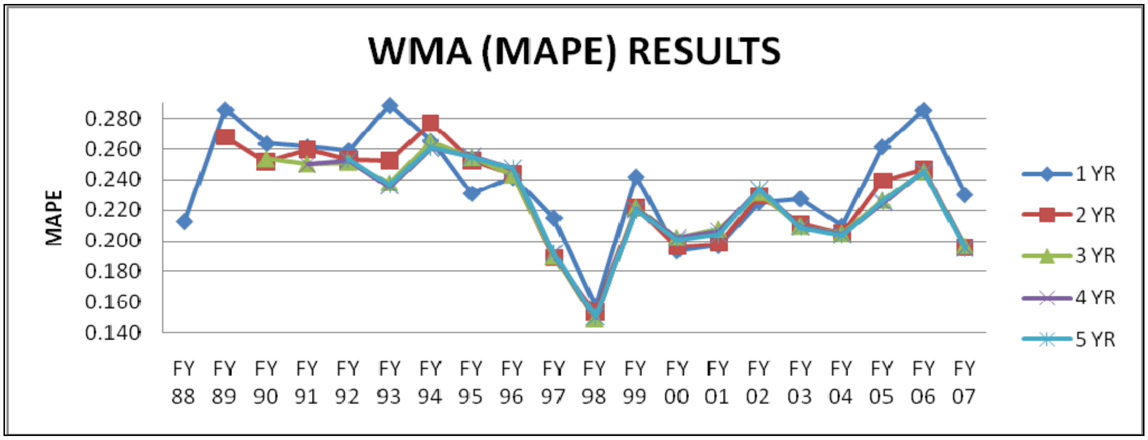

Figure 5. Weighted Moving Average MAPE Results

The MAPE rankings in Table 12 (less FY88-91), reveal that the one-year WMA MAPE is lowest during five years, the two-year WMA MAPE is lowest during one year, the three-year WMA MAPE is the lowest during two years, the four-year WMA MAPE is lowest during four years, and the five-year WMA MAPE is lowest during four years.

	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
1 YR	1	2	3	4	5	5	4	1	1	5	5	5	1	1	1	5	5	5	5	5
2 YR		1	1	3	4	4	5	2	3	1	4	3	2	2	2	4	4	4	4	3
3 YR			2	2	1	3	3	3	2	2	1	4	5	5	3	3	3	3	2	4
4 YR				1	2	1	1	5	5	3	2	2	4	4	4	2	2	1	1	2
5 YR					2	2	2	4	4	4	3	1	3	3	5	1	1	2	3	1

Table 12. Weighted Moving Average MAPE Rankings

V. CONCLUSION

A. SUMMARY

The purpose of this thesis is to analyze historical USMC enlisted attrition behavior and apply time series forecasting techniques by grade and YOS in order to identify methods to improve manpower analysts' ability to effectively forecast attrition behavior. The application of time series forecasting techniques to analyze historical enlisted end strength data by grade and YOS provides sufficient evidence that in most instances a one-year MA model is superior to that of the two- to five-year MA and one- to five-year WMA models. Depending on the goal of manpower analysts forecasting attrition by grade and YOS, the MSE and MAPE MOE's of the forecasts are interchangeable.

B. RECOMMENDATIONS

1. Research Question One

Of the techniques most accessible to manpower analysts, which of these best forecast enlisted attrition behavior in the Marine Corps by grade and YOS?

Analysis of the MA and WMA time series forecasting techniques and application of one- to five-year estimation models provide sufficient evidence that a one-year MA model is the best technique to utilize when forecasting attrition by grade and YOS. In fact, the optimal weights for the WMA models are equivalent to a one-year MA model.

This fact is important to understand in the field of manpower analysis. In the complex and rapidly changing environment of manpower analysis, time is a precious commodity that must be rationed appropriately among competing requirements. More importantly, the ability to rapidly estimate accurate attrition forecasts by grade and YOS allows manpower analysts to gain time to focus their efforts on other key responsibilities. Forecasting enlisted attrition by grade and YOS is a simple and flexible method for manpower analysts to utilize. The grade and AFADBD variables are reliable when

extracted from historical database archives such as the TFDW. The calculation of YOS from the AFADBD is simple to execute in the SAS program currently used by manpower analysts.

Based on this analysis, the recommendation to MPP-20 and MPP-50 is that the use of a one-year MA forecasting technique is the most effective way to estimate enlisted attrition rates in the Marine Corps by grade and YOS in comparison to the other models used in this study.

2. Research Question Two

How does the choice of technique depend on the measure of effectiveness?

This study found statistical significance only in the MA models using MSE, but not using MAPE. The one- and two-year models are significantly different and better in comparison to the four- and five-year models. The three-year model is not significantly different from the four other year models using MSE.

In contrast, the WMA models have no practical or statistical significant difference using MSE or MAPE. Further analysis of the MSE and MAPE measurements of accuracy of the estimates provide evidence that either MSE or MAPE are appropriate MOE's depending on the density of the population of interest.

Based on this analysis, the recommendation to MPP-20 and MPP-50 is that regardless of the MOE, a one-year MA forecasting model is superior to the other models analyzed in this study.

APPENDIX A: END STRENGTH BY FISCAL YEAR

Grade & YOS		FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
E1	0	10085	11943	10631	10198	7337	8443	10237	10598	10730	12076	12943	12229	11944	12257	11443	10986	12626	11772	12813	12562	14578	15278
E1	1	630	632	621	520	397	353	343	425	468	502	602	643	685	684	656	704	565	533	629	647	643	771
E1	2	360	330	381	357	294	303	202	206	248	277	338	330	366	346	333	390	326	333	348	279	269	326
E1	3	234	229	209	257	189	237	177	117	144	203	194	232	231	234	218	259	237	239	253	213	157	215
E1	4	64	67	80	63	84	63	67	52	37	57	81	75	71	70	72	94	82	81	91	57	63	61
E1	5	37	33	40	44	42	43	31	28	27	38	39	53	42	28	34	46	45	36	32	32	21	33
E2	0	15092	14994	14667	14489	13576	15112	15579	14248	14314	14233	14632	14451	14878	13705	13669	14326	14262	13261	14029	14096	14715	16907
E2	1	4436	4317	4714	4313	3805	1931	3430	3806	4109	3729	4730	4534	4659	4616	4478	4282	4132	4720	4758	4882	4946	5857
E2	2	1058	1037	1061	999	858	828	705	633	771	738	746	836	913	925	1047	917	795	886	807	825	829	992
E2	3	792	673	588	630	621	599	491	331	407	474	494	481	475	524	546	566	516	595	529	507	416	506
E2	4	154	164	114	156	190	87	90	53	69	121	81	80	60	69	78	94	92	95	116	81	70	77
E2	5	82	59	50	53	53	41	35	21	21	36	26	29	20	16	19	25	13	14	24	17	25	26
E3	0	4793	3899	3605	3111	3575	4262	3706	2532	2667	2411	2252	2063	2225	1916	1942	2166	2175	2189	2078	1746	1802	1841
E3	1	19327	20799	22797	21245	21096	19666	20819	21775	19748	20217	19454	20181	19859	20291	19333	19079	20523	20812	18921	19787	19047	20961
E3	2	17437	17067	17315	20886	20613	18528	14454	15292	15917	15697	15324	13125	14349	15312	15409	15327	15113	16089	15234	13443	12950	13885
E3	3	12375	9893	8383	8203	10368	9151	7451	5259	6286	6487	5804	4431	4673	5639	5744	6127	5624	6436	5509	5112	4234	5565
E3	4	1351	1374	907	1011	1121	893	912	768	543	677	545	455	379	531	723	844	781	739	700	571	625	760
E3	5	612	477	396	470	454	466	234	204	245	189	201	188	146	134	187	177	146	147	141	156	129	172
E4	1	3119	1574	559	368	280	379	650	1048	860	871	976	1206	1049	894	805	712	841	842	1125	1246	1580	1334
E4	2	5980	6380	5902	4226	3092	3586	5089	6834	7997	6280	6597	9241	8769	7832	7717	6904	7111	7108	9110	9308	11066	9707
E4	3	11903	10394	12454	12780	13023	11987	12056	12017	13275	14469	13019	13584	13565	14017	13951	14177	14190	13355	14941	15738	15438	15663
E4	4	6126	6953	6207	7287	8225	6941	6034	5588	4955	4907	4639	3202	2999	3867	4329	4900	4822	4906	4929	4872	5739	6449
E4	5	4151	4251	4937	4456	4760	4848	3236	2744	2524	1989	1930	1318	1076	962	1096	1323	1204	1178	1215	1273	1326	2055
E4	6	2252	2162	2261	3030	2491	2069	1408	928	676	622	504	476	386	403	336	437	455	482	430	474	484	607
E4	7	707	812	860	974	1423	891	591	469	365	243	224	187	195	179	170	172	252	255	235	269	273	304
E4	8	196	188	273	259	288	261	135	82	101	108	81	70	61	78	70	69	57	72	76	62	83	93
E5	2	183	139	75	53	56	38	54	73	104	103	118	221	262	181	196	115	125	159	160	247	231	253
E5	3	971	726	596	394	220	241	344	426	692	1091	1225	2454	3084	2512	2524	1951	1892	1593	2051	2725	2797	2404
E5	4	1880	1768	1707	1500	1115	937	1283	1360	1588	2303	3008	3219	3444	4093	4500	4259	4346	3757	3865	4324	5216	6057
E5	5	3612	3409	3443	2980	3070	2635	2680	2932	2749	3338	4021	4954	3890	4041	4857	5012	5045	4706	4623	4605	5024	6178
E5	6	5267	4963	4689	4300	3301	3058	3195	3196	2988	3239	3494	4010	4240	3830	3991	4700	5193	5056	4921	4843	4844	5005
E5	7	5045	5395	5148	4780	4887	3789	3537	3412	3144	2959	3148	3238	3406	3463	3162	3208	3681	4177	4454	4180	4165	3959
E5	8	3837	3910	4408	4189	4230	4411	3325	3123	2793	2394	2237	2184	1920	1862	1800	1649	1609	1921	2469	2270	2286	2162
E5	9	2248	2774	2929	3307	3452	3390	3621	2860	2341	2153	1768	1424	1198	1122	1020	963	760	901	1224	1230	1246	1068
E5	10	1025	1412	1745	1997	2483	2611	2444	2779	2019	1790	1432	875	628	669	497	493	512	455	577	661	778	667
E5	11	466	599	792	1062	1494	1776	1581	1603	1773	1433	971	588	356	294	267	248	282	330	314	335	450	439
E5	12	144	167	254	379	684	842	810	716	815	1038	531	340	194	134	108	128	146	170	202	167	201	224
E5	13	48	54	58	110	209	263	218	184	197	258	161	72	33	41	24	23	29	30	36	32	36	35
E6	5	48	41	32	26	16	12	15	21	16	23	19	36	40	38	55	64	76	48	37	48	98	122
E6	6	146	129	102	79	51	59	34	19	58	38	84	109	210	248	279	384	403	344	232	230	297	545
E6	7	462	341	301	267	207	178	128	54	151	151	182	344	582	846	870	936	1331	1227	887	900	856	1125
E6	8	1337	832	676	675	469	411	329	184	370	347	448	584	959	1212	1480	1445	1703	2004	1717	1733	1579	1830
E6	9	2621	1860	1285	1295	1005	745	726	488	668	617	712	998	1251	1405	1637	1916	1982	2040	2217	2328	2103	2266
E6	10	2947	2886	2377	1856	1697	1292	1195	1120	1053	918	1054	1349	1471	1456	1707	1789	2070	1955	2042	2353	2385	2348
E6	11	2468	2889	3057	2652	2076	1861	1801	1712	1764	1329	1431	1572	1577	1525	1565	1637	1698	1819	1756	1831	2039	2143
E6	12	2017	2221	2715	2948	2666	2053	2157	2159	2027	2045	1850	1694	1626	1402	1351	1348	1374	1302	1539	1316	1405	1466
E6	13	1325	1623	1908	2301	2649	2326	2015	2176	2029	1984	2285	1812	1490	1347	1132	1042	1018	944	1015	1014	898	926
E6	14	884	1002	1178	1452	1849	2070	1930	1825	1825	1768	1798	1891	1401	1120	972	746	652	678	721	630	698	622
E6	15	521	648	698	835	1116	1272	1367	1624	1272	1372	1298	1177	1231	980	723	605	457	430	502	483	476	545
E6	16	292	401	438	516	652	807	835	1092	939	886	857	745	697	796	583	467	393	331	309	351	389	388
E6	17	207	223	258	333	400	486	505	685	632	676	525	510	473	449	518	424	344	310	254	245	291	325
E6	18	149	166	151	219	274	317	352	448	497	538	493	403	384	378	363	420	357	302	255	220	205	258
E6	19	102	130	119	132	202	243	281	324	373	477	474	446	368	347	350	328	378	324	272	241	199	195
E6	20	13	17	21	20	23	24	33	34	38	47	62	58	42	40	29	39	55	49	41	22	26	25
E7	9	71	39	24	14	7	14	23	8	9	9	21	16	13	17	28	52	35	43	40	45	52	53
E7	10	227	105	58	44	29	32	28	31	30	23	15	32	31	33	57	83	124	120	127	159	166	165
E7	11	371	331	176	117	78	107	64	60	80	55	41	47	64	77	132	181	228	357	284	366	423	537
E7	12	806	524	496	342	208	223	189	127	181	131	108	131	132	190	239	313	410	570	559	658	659	925
E7	13	1028	1066	714	763	538	478	354	283	330	297	277	268	343	332	410	489	598	762	796	1000	979	1058
E7	14	1370	1263	1377	1092	1098	959	779	468	587	550	510	603	617	630	628	725	821	862	913	1088	1194	1141
E7	15	1441	1517	1461	1615	1322	1512	1380	955	924	925	925	1044	1163	949	959	932	939	980	974	1033	1126	1161
E7	16	1326	1403	1579	1535	1656	1501	1710	1476	1533	1245	1369	1398	1426	1482	1247	1152	1064	999	1028	1005	967	969
E7	17	1118	1213	1347	1468	1468	1610	1575	1644	1754	1615	1454	1577	1524	1535	1656	1308	1133	1032	949	906	842	736
E7	18	772	967	1018	1086	1303	1322	1494	1434	1530	1661	1603	1432	1518	1430	1464	1591	1191	1058	895	738	677	607
E7	19	538	640	736	825	930	1055	1110	1245	1197	1327	1419	1412	1277	1316	1211	1286	1319	1075	804	652	557	521
E7	20	151	240	229	289	375	303	403	420	449	477	552	617	621	557	517	509	572	620	400	275	258	202
E7	21	92	80	100	85	135	121	110	146	122	151	166	178	196	224	192	160	173	189	193	118	93	93
E7	22	28	59	28	37	28	15	21	22	15	20	16	15	13	17	20	27	28	21	13	22	26	22
E8	14	42	37	42	24	38	16	15	11	4	3	9	13	9	8	6	15	9	17	22	24	47	70
E8	15	86	77	76	77	62	82	40	23	31	20	20	21	30	23	23	12	31	31	38	70	99	164
E8	16	233	211	181	137	186	105	134	83	68	64	60	49	66	61	55	43	57	68	72	120	186	293
E8	17	470	374	355	356	272	282	162	196	202	153	136	134	143	147	120	113	160	136	167	227	324	447

Grade & YOS		FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
E8	18	699	645	615	614	545	440	418	293	454	330	299	250	283	296	280	261	278	264	315	390	479	565
E8	19	883	817	873	799	746	774	639	639	574	668	605	519	424	489	528	481	562	400	526	552	561	626
E8	20	507	709	616	714	612	670	738	646	717	610	705	724	614	565	590	584	610	636	527	573	547	505
E8	21	376	367	470	448	506	454	533	581	518	589	530	647	677	589	537	578	587	558	618	481	461	410
E8	22	207	248	229	287	318	318	343	342	394	397	409	437	487	537	468	442	495	464	445	462	345	327
E8	23	146	123	159	147	196	174	207	189	204	271	257	285	290	334	357	340	332	356	297	267	308	220
E8	24	68	93	71	97	93	118	97	127	108	127	152	168	164	167	169	236	208	215	186	152	131	168
E8	25	64	37	48	40	58	58	66	44	54	61	72	92	94	87	67	96	116	129	106	75	78	55
E8	26	46	36	18	29	28	30	26	30	17	24	19	30	44	35	30	41	43	49	53	38	17	34
E8	27	13	8	4	9	6	7	2	5	3	2	3	1	2	3	7	6	7	4	4	5	4	4
E9	19	49	39	36	29	33	31	25	26	23	17	21	17	16	10	16	7	11	11	14	13	26	26
E9	20	80	75	65	83	58	48	48	45	59	42	45	35	36	29	32	26	30	22	19	31	43	49
E9	21	127	112	150	115	124	100	83	76	77	97	56	66	64	59	53	54	45	46	44	55	68	86
E9	22	92	176	158	215	145	170	133	125	130	97	127	65	107	97	95	75	77	78	77	103	113	108
E9	23	148	145	206	177	230	197	191	174	169	165	141	140	112	146	182	130	123	117	125	136	164	156
E9	24	148	169	157	217	177	235	196	200	189	173	208	149	185	163	216	230	196	164	179	185	185	216
E9	25	153	158	181	154	214	174	227	184	202	187	173	197	161	191	201	227	267	210	202	225	206	203
E9	26	174	133	139	158	127	166	152	196	159	175	161	155	167	158	182	185	217	245	224	193	216	195
E9	27	183	162	103	119	135	104	132	120	164	135	144	144	135	146	143	163	179	192	222	200	173	192
E9	28	114	166	127	77	92	112	82	114	105	137	108	124	117	108	129	123	143	155	163	190	166	154
E9	29	104	91	129	105	64	68	96	63	88	82	120	95	105	98	88	117	102	120	118	131	161	147
E9	30	14	25	14	10	16	9	10	16	7	16	16	11	9	13	5	10	18	15	17	17	13	39

APPENDIX B: ATTRITION NUMBERS BY FISCAL YEAR

Grade & YOS		FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
E1	0	1331	1392	1446	1473	1041	1041	1500	1536	1434	1617	1965	1580	1567	1622	1440	1378	1291	1175	1521	1384	1363
E1	1	370	361	319	207	198	210	185	226	266	282	325	344	346	326	311	321	266	213	268	240	195
E1	2	258	228	246	201	187	206	146	129	162	189	220	202	241	238	209	219	199	168	183	158	135
E1	3	219	194	184	185	158	194	161	99	117	180	161	197	201	205	191	216	208	194	226	180	126
E1	4	53	54	58	40	56	43	51	39	18	39	45	54	55	59	53	75	67	67	74	46	49
E1	5	27	28	31	27	29	28	15	14	10	26	28	32	24	26	30	27	30	24	23	26	13
E2	0	1295	1189	1157	1302	1277	1347	1533	1321	1288	1282	1280	1065	1232	1055	1103	977	849	771	902	830	781
E2	1	718	662	560	421	545	361	590	535	567	542	558	511	462	483	480	362	334	332	314	343	306
E2	2	418	371	318	282	306	355	319	251	293	246	248	238	229	268	285	187	162	171	163	119	119
E2	3	630	521	449	419	496	510	409	284	345	381	435	407	398	437	443	445	426	446	446	379	293
E2	4	59	58	33	57	100	59	68	41	31	38	32	31	32	45	53	77	70	68	95	65	44
E2	5	40	25	22	23	34	30	30	17	12	13	18	15	8	5	11	11	8	10	11	6	9
E3	0	329	265	223	171	264	265	217	134	161	133	121	104	98	76	88	94	75	62	99	64	55
E3	1	1406	1586	1360	1040	1600	1293	1445	1293	1289	1395	1160	1077	930	965	850	663	894	762	788	671	569
E3	2	2103	1802	1669	1555	2023	1930	1514	1371	1408	1508	1162	918	921	871	891	662	748	737	812	583	526
E3	3	8493	7183	5956	5823	7626	6223	5134	3807	4648	4923	4437	3472	3324	3768	3561	3755	3504	4226	3726	3094	2264
E3	4	377	413	225	327	457	456	513	468	234	256	223	220	201	260	418	533	587	520	449	348	357
E3	5	183	117	99	145	212	224	129	151	102	84	71	82	41	40	65	44	37	45	34	39	31
E4	1	166	73	24	14	13	23	22	42	37	33	31	39	27	27	18	7	19	25	23	29	37
E4	2	503	490	388	258	226	275	367	527	519	429	363	402	350	253	232	131	167	230	250	233	235
E4	3	6529	5263	5767	5626	7237	6842	6902	6807	7652	8723	8398	9086	8215	8042	7714	7809	8054	7338	8434	8288	6421
E4	4	708	838	634	1094	1890	1954	1643	1638	1220	1184	1082	989	869	1180	1572	1956	2108	1932	2033	1885	1737
E4	5	424	470	596	917	1575	1960	1101	1150	798	577	550	357	158	124	136	123	160	152	142	137	105
E4	6	460	418	502	550	645	512	334	192	143	66	84	77	52	38	43	40	43	56	60	60	56
E4	7	281	297	348	404	734	469	303	238	180	53	81	85	91	99	97	94	149	133	155	159	152
E4	8	66	65	95	85	120	109	57	44	43	19	24	20	19	21	27	32	25	31	40	32	42
E5	2	22	5	9	5	5	10	13	13	13	13	10	12	15	10	9	3	2	13	15	13	12
E5	3	359	187	125	77	47	77	119	143	238	406	563	1359	1633	1183	1182	884	880	644	909	1290	1058
E5	4	183	154	147	156	199	208	207	257	271	400	485	627	689	922	1066	1119	1268	1070	1091	1143	1139
E5	5	327	384	513	889	1228	1048	741	879	677	797	925	1174	446	393	404	298	325	248	266	259	236
E5	6	730	631	596	434	406	456	402	348	307	306	297	373	331	258	268	254	370	284	241	251	206
E5	7	969	972	884	679	712	602	553	483	657	533	636	710	878	918	816	737	930	1081	1218	1134	956
E5	8	449	434	464	402	540	506	317	270	337	255	233	267	266	268	227	204	188	260	437	402	341
E5	9	340	352	282	340	464	449	387	220	235	213	180	188	197	171	116	93	104	113	141	113	97
E5	10	190	209	208	174	356	407	236	246	220	204	178	127	120	100	58	51	57	57	74	85	71
E5	11	158	146	184	166	423	469	345	261	294	214	175	151	137	73	45	32	57	69	73	75	108
E5	12	44	47	68	87	306	348	352	293	308	338	230	178	104	66	45	63	92	110	112	100	120
E5	13	11	11	19	33	79	106	113	73	81	88	73	34	14	19	3	4	16	6	5	17	14
E6	5	6	9	8	3	4	1	2	4	2	2	5	5	6	3	6	8	8	2	4	6	9
E6	6	15	18	9	7	4	3	2	2	4	2	4	13	15	16	13	22	27	17	9	15	10
E6	7	64	50	34	23	12	16	13	5	18	20	19	57	92	146	150	137	193	197	155	148	127
E6	8	109	76	61	60	49	48	24	14	35	29	33	62	105	160	145	130	156	214	185	238	185
E6	9	191	147	77	78	82	55	53	37	73	83	78	128	132	122	219	154	152	130	170	169	122
E6	10	202	182	143	85	100	87	71	71	74	79	113	119	111	100	135	94	130	120	131	156	133
E6	11	223	209	209	137	137	138	118	98	100	112	103	120	139	122	120	98	102	109	135	178	142
E6	12	119	128	146	138	161	137	142	129	150	134	100	99	106	74	82	68	70	63	94	89	77
E6	13	71	87	66	88	170	173	119	100	87	79	111	68	74	72	52	39	46	47	56	51	36
E6	14	35	41	47	45	126	242	125	71	74	70	60	71	52	41	31	30	21	23	40	22	35
E6	15	25	35	33	31	76	164	158	63	44	42	43	41	49	33	19	17	10	11	25	23	12
E6	16	14	20	16	21	53	112	88	31	51	39	39	31	27	23	16	10	8	9	9	6	17
E6	17	6	11	6	10	33	55	45	23	23	27	13	22	16	6	7	6	4	7	7	3	6
E6	18	3	3	6	4	13	19	21	8	4	9	4	3	4	4	5		3	6	1	3	1
E6	19	79	101	99	104	179	207	247	262	322	412	413	391	327	315	309	269	332	280	250	216	175
E6	20	9	15	19	19	21	22	31	30	36	47	61	57	42	39	27	36	53	48	39	22	23
E7	9	5	3	1	2	1		1				1	1		3	5	6	2		3	1	3
E7	10	9	6	3	2		2	2	3	4	4	1	6	3	3	5	11	13	11	12	20	13
E7	11	26	18	9	8	8	10	1	4	7	2	4	8	5	4	9	11	15	22	15	24	36
E7	12	28	26	21	10	6	12	8	6	9	14	7	9	8	15	13	17	23	21	30	29	33
E7	13	27	36	31	18	16	12	14	7	16	14	13	11	17	15	18	21	20	19	35	40	29
E7	14	21	26	25	23	21	32	16	12	23	23	21	20	28	18	25	24	21	16	36	27	34
E7	15	20	22	20	22	38	48	15	26	26	21	24	28	32	32	25	21	19	20	16	22	35
E7	16	19	28	23	17	47	41	30	21	22	12	13	13	25	17	21	12	19	13	15	13	13
E7	17	9	15	15	14	21	46	21	12	20	16	12	15	14	15	15	9	8	10	9	9	8
E7	18	9	16	7	15	19	22	16	10	8	6	8	6	7	5	7	8	4	4	3	1	2
E7	19	221	309	350	371	474	498	520	571	564	573	571	593	498	575	536	471	550	466	368	305	287
E7	20	46	95	108	121	193	154	198	217	228	213	251	280	248	249	231	184	307	278	210	132	133
E7	21	21	33	50	46	98	86	77	106	90	118	115	129	128	165	132	105	133	128	145	76	66
E7	22	9	28	18	21	21	8	18	15	13	16	13	13	8	11	14	21	26	16	11	14	18
E8	14	1	1							1												
E8	15	2		2		1	3		1									1	1	1	1	2
E8	16		1	2	2		1	5		1	1						1		1			
E8	17	2	1	5	3	1			1	1	1	1		1						1	2	
E8	18	7	3	5	1	1	3	2		4	1			1	1			2			3	

Grade & YOS		FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
E8	19	234	274	218	246	217	172	144	136	114	149	104	98	86	103	100	92	70	79	96	70	98
E8	20	132	192	134	192	168	133	181	168	147	151	141	142	141	109	111	123	112	147	82	120	121
E8	21	74	87	115	102	131	86	151	150	108	157	109	143	148	119	101	83	108	124	119	92	99
E8	22	35	38	39	50	86	73	96	81	82	87	96	90	112	88	87	62	92	105	111	87	74
E8	23	22	25	29	31	40	48	52	46	50	50	63	59	70	77	58	53	71	96	75	80	71
E8	24	12	19	9	22	16	32	31	47	28	28	43	40	42	43	47	60	48	47	55	34	40
E8	25	11	9	13	9	18	26	26	19	24	28	31	33	38	33	19	35	43	37	42	46	33
E8	26	25	30	8	21	16	27	20	20	14	21	14	28	35	23	19	27	35	36	40	29	12
E8	27	6	7	2	3	5	6	1	3	3	1	2	1	2	3	6	4	7	4	4	2	2
E9	19	11	10	2	4	7	4	3	3	1	4	6		3	1				1	2		1
E9	20	10	15	8	8	8	6	3	4	5	5	3	6	4	4	2	6	2		3	2	4
E9	21	17	23	16	13	26	5	7	9	11	11	11	10	9	8	7	5	4	8	3	6	7
E9	22	13	37	27	33	17	22	18	12	8	11	16	12	5	10	8	5	10	16	9	9	8
E9	23	14	17	28	26	36	30	25	24	23	27	18	19	8	22	17	13	8	14	15	10	18
E9	24	12	16	21	20	21	27	28	24	20	26	27	20	29	17	12	24	16	23	10	17	17
E9	25	35	30	29	32	59	29	40	32	29	40	29	44	23	32	23	31	44	25	36	20	23
E9	26	28	33	24	26	29	34	33	39	29	31	22	21	27	20	24	13	29	33	32	25	23
E9	27	25	35	26	29	24	22	20	17	28	28	22	29	28	18	20	25	26	32	32	35	21
E9	28	22	36	22	13	22	16	18	25	22	17	11	17	19	19	11	18	21	34	32	27	20
E9	29	79	76	119	89	55	58	80	56	73	65	109	86	92	93	78	98	89	103	100	118	123
E9	30	13	22	13	6	15	7	9	14	7	16	16	9	9	11	5	10	17	13	16	15	11

APPENDIX C: ATTRITION RATES BY FISCAL YEAR

Grade & YOS		FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
E1	0	0.132	0.117	0.136	0.144	0.142	0.123	0.147	0.145	0.134	0.134	0.152	0.129	0.131	0.132	0.126	0.125	0.102	0.100	0.119	0.110	0.093
E1	1	0.587	0.571	0.514	0.398	0.499	0.595	0.539	0.532	0.568	0.562	0.540	0.535	0.505	0.477	0.474	0.456	0.471	0.400	0.426	0.371	0.303
E1	2	0.717	0.691	0.646	0.563	0.636	0.680	0.723	0.626	0.653	0.682	0.651	0.612	0.658	0.688	0.628	0.562	0.610	0.505	0.526	0.566	0.502
E1	3	0.936	0.847	0.880	0.720	0.836	0.819	0.910	0.846	0.813	0.887	0.830	0.849	0.870	0.876	0.876	0.834	0.878	0.812	0.893	0.845	0.803
E1	4	0.828	0.806	0.725	0.635	0.667	0.683	0.761	0.750	0.486	0.684	0.556	0.720	0.775	0.843	0.736	0.798	0.817	0.827	0.813	0.807	0.778
E1	5	0.730	0.848	0.775	0.614	0.690	0.651	0.484	0.500	0.370	0.684	0.718	0.604	0.571	0.929	0.882	0.587	0.667	0.667	0.719	0.813	0.619
E2	0	0.086	0.079	0.079	0.090	0.094	0.089	0.098	0.093	0.090	0.090	0.087	0.074	0.083	0.077	0.081	0.068	0.060	0.058	0.064	0.059	0.053
E2	1	0.162	0.153	0.119	0.098	0.143	0.187	0.172	0.141	0.138	0.145	0.118	0.113	0.099	0.105	0.107	0.085	0.081	0.070	0.066	0.070	0.062
E2	2	0.395	0.358	0.300	0.282	0.357	0.429	0.452	0.397	0.380	0.333	0.332	0.285	0.251	0.290	0.272	0.204	0.204	0.193	0.202	0.144	0.144
E2	3	0.795	0.774	0.764	0.665	0.799	0.851	0.833	0.858	0.848	0.804	0.881	0.846	0.838	0.834	0.811	0.786	0.826	0.750	0.843	0.748	0.704
E2	4	0.383	0.354	0.289	0.365	0.526	0.678	0.756	0.774	0.449	0.314	0.395	0.388	0.533	0.652	0.679	0.819	0.761	0.716	0.819	0.802	0.629
E2	5	0.488	0.424	0.440	0.434	0.642	0.732	0.857	0.810	0.571	0.361	0.692	0.517	0.400	0.313	0.579	0.440	0.615	0.714	0.458	0.353	0.360
E3	0	0.069	0.068	0.062	0.055	0.074	0.062	0.059	0.053	0.060	0.055	0.054	0.050	0.044	0.040	0.045	0.043	0.034	0.028	0.048	0.037	0.031
E3	1	0.073	0.076	0.060	0.049	0.076	0.066	0.069	0.059	0.065	0.069	0.060	0.053	0.047	0.048	0.044	0.035	0.044	0.037	0.042	0.034	0.030
E3	2	0.121	0.106	0.096	0.074	0.098	0.104	0.105	0.090	0.088	0.096	0.076	0.070	0.064	0.057	0.058	0.043	0.049	0.046	0.053	0.043	0.041
E3	3	0.686	0.726	0.710	0.710	0.736	0.680	0.689	0.724	0.739	0.759	0.764	0.784	0.711	0.668	0.620	0.613	0.623	0.657	0.676	0.605	0.535
E3	4	0.279	0.301	0.248	0.323	0.408	0.511	0.563	0.609	0.431	0.378	0.409	0.484	0.530	0.490	0.578	0.632	0.752	0.704	0.641	0.609	0.571
E3	5	0.299	0.245	0.250	0.309	0.467	0.481	0.551	0.740	0.416	0.444	0.353	0.436	0.281	0.299	0.348	0.249	0.253	0.306	0.241	0.250	0.240
E4	1	0.053	0.046	0.043	0.038	0.046	0.061	0.034	0.040	0.043	0.038	0.032	0.032	0.026	0.030	0.022	0.010	0.023	0.030	0.020	0.023	0.023
E4	2	0.084	0.077	0.066	0.061	0.073	0.077	0.072	0.077	0.065	0.068	0.055	0.044	0.040	0.032	0.030	0.019	0.023	0.032	0.027	0.025	0.021
E4	3	0.549	0.506	0.463	0.440	0.556	0.571	0.572	0.566	0.576	0.603	0.645	0.669	0.606	0.574	0.553	0.551	0.568	0.549	0.564	0.527	0.416
E4	4	0.116	0.121	0.102	0.150	0.230	0.282	0.272	0.293	0.246	0.241	0.233	0.309	0.290	0.305	0.363	0.399	0.437	0.394	0.412	0.387	0.303
E4	5	0.102	0.111	0.121	0.206	0.331	0.404	0.340	0.419	0.316	0.290	0.285	0.271	0.147	0.129	0.124	0.093	0.133	0.129	0.117	0.108	0.079
E4	6	0.204	0.193	0.222	0.182	0.259	0.247	0.237	0.207	0.212	0.106	0.167	0.162	0.135	0.094	0.128	0.092	0.095	0.116	0.140	0.127	0.116
E4	7	0.397	0.366	0.405	0.415	0.516	0.526	0.513	0.507	0.493	0.218	0.362	0.455	0.467	0.553	0.571	0.547	0.591	0.522	0.660	0.591	0.557
E4	8	0.337	0.346	0.348	0.328	0.417	0.418	0.422	0.537	0.426	0.176	0.296	0.286	0.311	0.269	0.386	0.464	0.439	0.431	0.526	0.516	0.506
E5	2	0.120	0.036	0.120	0.094	0.089	0.263	0.241	0.178	0.125	0.126	0.085	0.054	0.057	0.055	0.046	0.026	0.016	0.082	0.094	0.053	0.052
E5	3	0.370	0.258	0.210	0.195	0.214	0.320	0.346	0.336	0.344	0.372	0.460	0.554	0.530	0.471	0.468	0.453	0.465	0.404	0.443	0.473	0.378
E5	4	0.097	0.087	0.086	0.104	0.178	0.222	0.161	0.189	0.171	0.174	0.161	0.195	0.200	0.225	0.237	0.263	0.292	0.285	0.282	0.264	0.218
E5	5	0.091	0.113	0.149	0.298	0.400	0.398	0.276	0.300	0.246	0.239	0.230	0.237	0.115	0.097	0.083	0.059	0.064	0.053	0.058	0.056	0.047
E5	6	0.139	0.127	0.127	0.101	0.123	0.149	0.126	0.109	0.103	0.094	0.085	0.093	0.078	0.067	0.067	0.054	0.071	0.056	0.049	0.052	0.043
E5	7	0.192	0.180	0.172	0.142	0.146	0.159	0.156	0.142	0.209	0.180	0.202	0.219	0.258	0.265	0.258	0.230	0.253	0.259	0.273	0.271	0.230
E5	8	0.117	0.111	0.105	0.096	0.128	0.115	0.095	0.086	0.121	0.107	0.104	0.122	0.139	0.144	0.126	0.124	0.117	0.135	0.177	0.177	0.149
E5	9	0.151	0.127	0.096	0.103	0.134	0.132	0.107	0.077	0.100	0.099	0.102	0.132	0.164	0.152	0.114	0.097	0.137	0.125	0.115	0.092	0.078
E5	10	0.185	0.148	0.119	0.087	0.143	0.156	0.097	0.089	0.109	0.114	0.124	0.145	0.191	0.149	0.117	0.103	0.111	0.125	0.128	0.129	0.091
E5	11	0.339	0.244	0.232	0.156	0.283	0.264	0.218	0.163	0.166	0.149	0.180	0.257	0.385	0.248	0.169	0.129	0.202	0.209	0.232	0.224	0.240
E5	12	0.306	0.281	0.268	0.230	0.447	0.413	0.435	0.409	0.378	0.326	0.433	0.524	0.536	0.493	0.417	0.492	0.630	0.647	0.554	0.599	0.597
E5	13	0.229	0.204	0.328	0.300	0.378	0.403	0.518	0.397	0.411	0.341	0.453	0.472	0.424	0.463	0.125	0.174	0.552	0.200	0.139	0.531	0.389
E6	5	0.125	0.220	0.250	0.115	0.250	0.083	0.133	0.190	0.125	0.087	0.263	0.139	0.150	0.079	0.109	0.125	0.105	0.042	0.108	0.125	0.092
E6	6	0.103	0.140	0.088	0.089	0.078	0.051	0.059	0.105	0.069	0.053	0.048	0.119	0.071	0.065	0.047	0.057	0.067	0.049	0.039	0.065	0.034
E6	7	0.139	0.147	0.113	0.086	0.058	0.090	0.102	0.093	0.119	0.132	0.104	0.166	0.158	0.173	0.172	0.146	0.145	0.161	0.175	0.164	0.148
E6	8	0.082	0.091	0.090	0.089	0.104	0.117	0.073	0.076	0.095	0.084	0.074	0.106	0.109	0.132	0.098	0.090	0.092	0.107	0.108	0.137	0.117
E6	9	0.073	0.079	0.060	0.060	0.082	0.074	0.073	0.076	0.109	0.135	0.110	0.128	0.106	0.087	0.134	0.080	0.077	0.064	0.077	0.073	0.058
E6	10	0.069	0.063	0.060	0.046	0.059	0.067	0.059	0.063	0.070	0.086	0.107	0.088	0.075	0.069	0.079	0.053	0.063	0.061	0.064	0.066	0.056
E6	11	0.090	0.072	0.068	0.052	0.066	0.074	0.066	0.057	0.057	0.084	0.072	0.076	0.088	0.080	0.077	0.060	0.060	0.060	0.077	0.097	0.070
E6	12	0.059	0.058	0.054	0.047	0.060	0.067	0.066	0.060	0.074	0.066	0.054	0.058	0.065	0.053	0.061	0.050	0.051	0.048	0.061	0.068	0.055
E6	13	0.054	0.054	0.035	0.038	0.064	0.074	0.059	0.046	0.043	0.040	0.049	0.038	0.050	0.053	0.046	0.037	0.045	0.050	0.055	0.050	0.040
E6	14	0.040	0.041	0.040	0.031	0.068	0.117	0.065	0.039	0.041	0.040	0.033	0.038	0.037	0.037	0.032	0.040	0.032	0.034	0.055	0.035	0.050
E6	15	0.048	0.054	0.047	0.037	0.068	0.129	0.116	0.039	0.035	0.031	0.033	0.035	0.040	0.034	0.026	0.028	0.022	0.026	0.050	0.048	0.025
E6	16	0.048	0.050	0.037	0.041	0.081	0.139	0.105	0.028	0.054	0.044	0.046	0.042	0.039	0.029	0.027	0.021	0.020	0.027	0.029	0.017	0.044
E6	17	0.029	0.049	0.023	0.030	0.083	0.113	0.089	0.034	0.036	0.040	0.025	0.043	0.034	0.013	0.014	0.014	0.012	0.023	0.028	0.012	0.021
E6	18	0.020	0.018	0.040	0.018	0.047	0.060	0.060	0.018	0.008	0.017	0.008	0.007	0.010	0.011	0.014	0.000	0.008	0.020	0.004	0.014	0.005
E6	19	0.775	0.777	0.832	0.788	0.886	0.852	0.879	0.809	0.863	0.864	0.871	0.877	0.889	0.908	0.883	0.820	0.878	0.864	0.919	0.896	0.879
E6	20	0.692	0.882	0.905	0.950	0.913	0.917	0.939	0.882	0.947	1.000	0.984	0.983	1.000	0.975	0.931	0.923	0.964	0.980	0.951	1.000	0.885
E7	9	0.070	0.077	0.042	0.143	0.143	0.000	0.043	0.000	0.000	0.000	0.048	0.063	0.000	0.176	0.179	0.115	0.057	0.000	0.075	0.022	0.058
E7	10	0.040	0.057	0.052	0.045	0.000	0.063	0.071	0.097	0.133	0.174	0.067	0.188	0.097	0.091	0.088	0.133	0.105	0.092	0.094	0.126	0.078
E7	11	0.070	0.054	0.051	0.068	0.103	0.093	0.016	0.067	0.088	0.036	0.098	0.170	0.078	0.052	0.068	0.061	0.066	0.062	0.053	0.066	0.085
E7	12	0.035	0.050	0.042	0.029	0.029	0.054	0.042	0.047	0.050	0.107	0.065	0.069	0.061	0.079	0.054	0.054	0.056	0.037	0.054	0.044	0.050
E7	13	0.026	0.034	0.043	0.024	0.030	0.025	0.040	0.025	0.048	0.047	0.047	0.041	0.050	0.045	0.044	0.043	0.033	0.025	0.044	0.040	0.030
E7	14	0.015	0.021	0.018	0.021	0.019	0.033	0.021	0.026	0.039	0.042	0.041	0.033	0.045	0.029	0.040	0.033	0.026	0.019	0.039	0.025	0.028
E7	15	0.014	0.015	0.014	0.014	0.029	0.032	0.011	0.027	0.028	0.023	0.026	0.027	0.028	0.034	0.026	0.023	0.020	0.020	0.016	0.021	0.031
E7	16	0.014	0.020	0.015	0.011	0.028	0.027	0.018	0.014	0.014	0.010	0.009	0.009	0.018	0.011	0.017	0.010	0.018	0.013	0.015	0.013	0.013
E7	17	0.008	0.012	0.011	0.010	0.014	0.029	0.013	0.007	0.011	0.010	0.008	0.010	0.009	0.010	0.009	0.007	0.007	0.010	0.009	0.010	0.010
E7	18	0.012	0.017	0.007	0.014	0.015	0.017	0.011	0.007	0.005	0.004	0.005	0.004	0.005	0.003	0.005	0.005	0.003	0.004	0.003	0.001	0.003
E7	19	0.411	0.483	0.476	0.450	0.510	0.472	0.468	0.459	0.471	0.432	0.402	0.420	0.390	0.437	0.443	0.366	0.417	0.433	0.458	0.468	0.515
E7	20	0.305	0.396	0.472	0.419	0.515	0.508	0.491	0.517	0.508	0.447	0.455	0.454	0.399	0.447	0.447	0.361	0.537	0.448	0.525	0.480	0.516
E7	21	0.228	0.413	0.500	0.541	0.726	0.711	0.700	0.726	0.738	0.781	0.693	0.725	0.653	0.737	0.688	0.656	0.769	0.677	0.751	0.644	0.710
E7	22	0.321	0.475	0.643	0.568	0.750	0.533	0.857	0.682	0.867	0.800	0.813	0.867	0.615	0.647	0.700	0.778	0.929	0.762	0.846	0.636	0.692
E8	14	0.024	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E8	15	0.023	0.000	0.026	0.000	0.016	0.037	0.000	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.032	0.026	0.014	0.020
E8	16	0.000	0.005	0.011	0.015	0.000	0.010	0.037	0.000	0.015	0.016	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.015	0.000	0.000	0.000
E8	17	0.004	0.003	0.014	0.008	0.004	0.000	0.000	0.005	0.005	0.007	0.007	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.006	0.009	0.000

Grade & YOS		FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
E8	18	0.010	0.005	0.008	0.002	0.002	0.007	0.005	0.000	0.009	0.003	0.000	0.000	0.004	0.003	0.000	0.000	0.007	0.000	0.000	0.008	0.000
E8	19	0.265	0.335	0.250	0.308	0.291	0.222	0.225	0.213	0.199	0.223	0.172	0.189	0.203	0.211	0.189	0.191	0.125	0.198	0.183	0.127	0.175
E8	20	0.260	0.271	0.218	0.269	0.275	0.199	0.245	0.260	0.205	0.248	0.200	0.196	0.230	0.193	0.188	0.211	0.184	0.231	0.156	0.209	0.221
E8	21	0.197	0.237	0.245	0.228	0.259	0.189	0.283	0.258	0.208	0.267	0.206	0.221	0.219	0.202	0.188	0.144	0.184	0.222	0.193	0.191	0.215
E8	22	0.169	0.153	0.170	0.174	0.270	0.230	0.280	0.237	0.208	0.219	0.235	0.206	0.230	0.164	0.186	0.140	0.186	0.226	0.249	0.188	0.214
E8	23	0.151	0.203	0.182	0.211	0.204	0.276	0.251	0.243	0.245	0.185	0.245	0.207	0.241	0.231	0.162	0.156	0.214	0.270	0.253	0.300	0.231
E8	24	0.176	0.204	0.127	0.227	0.172	0.271	0.320	0.370	0.259	0.220	0.283	0.238	0.256	0.257	0.278	0.254	0.231	0.219	0.296	0.224	0.305
E8	25	0.172	0.243	0.271	0.225	0.310	0.448	0.394	0.432	0.444	0.459	0.431	0.359	0.404	0.379	0.284	0.365	0.371	0.287	0.396	0.613	0.423
E8	26	0.543	0.833	0.444	0.724	0.571	0.900	0.769	0.667	0.824	0.875	0.737	0.933	0.795	0.657	0.633	0.659	0.814	0.735	0.755	0.763	0.706
E8	27	0.462	0.875	0.500	0.333	0.833	0.857	0.500	0.600	1.000	0.500	0.667	1.000	1.000	1.000	0.857	0.667	1.000	1.000	1.000	0.400	0.500
E9	19	0.224	0.256	0.056	0.138	0.212	0.129	0.120	0.115	0.043	0.235	0.286	0.000	0.188	0.100	0.000	0.000	0.000	0.091	0.143	0.000	0.038
E9	20	0.125	0.200	0.123	0.096	0.138	0.125	0.063	0.089	0.085	0.119	0.067	0.171	0.111	0.138	0.063	0.231	0.067	0.000	0.158	0.065	0.093
E9	21	0.134	0.205	0.107	0.113	0.210	0.050	0.084	0.118	0.143	0.113	0.196	0.152	0.141	0.136	0.132	0.093	0.089	0.174	0.068	0.109	0.103
E9	22	0.141	0.210	0.171	0.153	0.117	0.129	0.135	0.096	0.062	0.113	0.126	0.185	0.047	0.103	0.084	0.067	0.130	0.205	0.117	0.087	0.071
E9	23	0.095	0.117	0.136	0.147	0.157	0.152	0.131	0.138	0.136	0.164	0.128	0.136	0.071	0.151	0.093	0.100	0.065	0.120	0.120	0.074	0.110
E9	24	0.081	0.095	0.134	0.092	0.119	0.115	0.143	0.120	0.106	0.150	0.130	0.134	0.157	0.104	0.056	0.104	0.082	0.140	0.056	0.092	0.092
E9	25	0.229	0.190	0.160	0.208	0.276	0.167	0.176	0.174	0.144	0.214	0.168	0.223	0.143	0.168	0.114	0.137	0.165	0.119	0.178	0.089	0.112
E9	26	0.161	0.248	0.173	0.165	0.228	0.205	0.217	0.199	0.182	0.177	0.137	0.135	0.162	0.127	0.132	0.070	0.134	0.135	0.143	0.130	0.106
E9	27	0.137	0.216	0.252	0.244	0.178	0.212	0.152	0.142	0.171	0.207	0.153	0.201	0.207	0.123	0.140	0.153	0.145	0.167	0.144	0.175	0.121
E9	28	0.193	0.217	0.173	0.169	0.239	0.143	0.220	0.219	0.210	0.124	0.102	0.137	0.162	0.176	0.085	0.146	0.147	0.219	0.196	0.142	0.120
E9	29	0.760	0.835	0.922	0.848	0.859	0.853	0.833	0.889	0.830	0.793	0.908	0.905	0.876	0.949	0.886	0.838	0.873	0.858	0.847	0.901	0.764
E9	30	0.929	0.880	0.929	0.600	0.938	0.778	0.900	0.875	1.000	1.000	1.000	0.818	1.000	0.846	1.000	1.000	0.944	0.867	0.941	0.882	0.846

LIST OF REFERENCES

Amos, J. F. *2011 Report to the House Armed Services Committee on the Posture of the United States Marine Corps*. http://www.marines.mil/unit/hqmc/cmc/Documents/110301_CMC_HASC_%20Posture.pdf (1 March 2011).

Conover, W. J. *Practical nonparametric statistics, 3rd Edition*. New York. John Wiley & Sons, Inc. 1999.

Hall, J. T. (2009). *Forecasting Marine Corps enlisted attrition through parametric modeling.* Master's thesis Naval Postgraduate School, Monterey, CA.

Hattiangadi, A. U., Kimble, T. H., Lambert, W. B. Quester, A. O. (2005). Center for Naval Analysis. *Endstrength: Forecasting Marine Corps losses final report*. Alexandria, VA: CNA.

MCBUL 5314 Enlisted Career Force Controls (ECFC) Program http://www.marines.mil/news/messages/Pages/MARADMIN505-10.aspx (10 September 2010).

Orrick, S.C. (2008). *Forecasting Marine Corps enlisted losses.* Master's thesis Naval Postgraduate School, Monterey, CA.

Ragsdale, Cliff T., *Spreadsheet modeling and decision analysis 3rd Edition*, Cincinnati, South-Western College Publishing, 2001.

Total Force Data Warehouse (TFDW). https://tfdw-web.manpower.usmc.mil. (Accessed 25 August 2010).

U.S. Marine Corps Concepts & Programs 2010. http://www.usmc.mil/unit/pandr/Documents/Concepts/2010/CP2010Index.html.

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